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Air Conditions and Health

Chemical Composition and Physical Qualities of Air

By THOMAS J. DUFFIELD, Executive Secretary, Committee on Research, American Society of Heating and Ventilating Engineers, formerly Executive Secretary and Director of Field Studies, New York Commission on Ventilation

IT is an unfortunate fact that at the present time in treating the subject of the relationship of air conditions to health, our story must deal largely with what we do not know rather than what is known. The truth is that it is only a relatively short time since the foremost scientists who have given the matter thought, have clarified their own ideas on the subject.

The average layman still fails to differentiate between the chemical and physical characteristics of air. He has been taught—generally by persons who knew little more about the matter than he did himself—that he should work, play and sleep in places plentifully supplied with "fresh" air, and he has been led to believe that outdoor air is always "fresh" and wholesome, while air indoors is generally vitiated and harmful. Neither of these impressions is unqualifiedly true.

What then are characteristics of air that affect our health? In its relation to man, air plays a dual rôle. In the first place, it serves as the source of the oxygen so necessary to our vital processes; in the second, it serves as the medium into which the body loses the excess heat it develops from the food we eat. Normally, part of the energy from this source is immediately required to keep bodily processes functioning; part of it is stored up for future use, and the remainder is lost—largely to the atmosphere, in the respired breath and in warming the air that comes in contact with our bodies and clothing.

As regards the first of these rôles, it is the chemical composition of the air that is important, and from this angle, we know of no better condition than one finds in nature, in spots well removed from centers of habitation and industry. Air is a mixture of gases and under such conditions it will be found that volumetric analysis would give approximately the results, shown in Table I.

Table I

CHEMICAL COMPOSITION OF AIR AT NORMAL TEMPERATURE AND BAROMETRIC PRESSURE AT SEA LEVEL

Gas	*Per cent by Volume*
Oxygen	20.93
Nitrogen	78.10
Carbon dioxide	0.03
Argon	0.94
Helium, krypton, neon, ozone, etc.	traces

At the present time, it appears that of all the gases that have been identified in the air, only two are of importance from the standpoint of respiration: oxygen, and carbon dioxide.

This belief has recently been questioned by a worker at one of our middle-western colleges, who states that the rare gases which were previously thought to be inert really are of vital importance. He contends, and supports his contentions with the results of animal experimentation, that life is not well supported by atmospheres that are too pure. Animals exposed to a mixture of purified oxygen, nitrogen and carbon dioxide, in the same proportions as they exist in nature, did not survive as well as did the control animals that were exposed to ordinary air. The suggestion warrants, and will have, further consideration.

Nitrogen, which comprises roughly four-fifths of the total volume, seems to be present simply as a diluent, because its concentration is unchanged in the breathing process, whereas the proportions of oxygen and carbon dioxide undergo vast changes. This fact is shown by the comparison of the analyses of inspired and expired air, which under normal conditions would give results approximately as shown in Table II.

Table II

COMPARISONS OF THE CHEMICAL COMPOSITION OF AIR BEFORE AND AFTER RESPIRATION

	Percent by Volume	
Gas	*Inspired Air*	*Expired Air*
Oxygen	20.93	16.0
Carbon dioxide	0.03	5.0
Nitrogen, argon, etc.	79.04	79.0

It is not the purpose of this paper to discuss the physiology of respiration, and we will dismiss this phase of the subject with the statement that unless the concentrations of oxygen and carbon dioxide in the air depart markedly from the normal, and approach or even exceed the figures given for expired air—conditions which are rarely met, and never in the course of an ordinary life—there appears to be little, if any, relationship between the chemical composition of the air and physiological reactions.

This fact was brought out strikingly in an investigation conducted a number of years ago in London by Leonard Hill and his associates. Hill repeated and supplemented studies that had earlier been made independently on the continent by Flügge and Hermans and their co-workers. In these studies by Hill, men were enclosed in a hermetically sealed chamber and kept there for hours. Provisions were made for renewing the air at a predetermined rate, or not at all; for stirring it up with electric fans; for heating, cooling and humidifying it; and for the gradual or sudden introduction of large quantities of carbon dioxide.

As far as the chemical composition of the air was concerned, no effect was noticed by the subjects even when the concentration of carbon dioxide was suddenly increased from normal to 2%. At 3%—100 times normal concentration—slightly deeper breathing occurred but no other effect was noticed. At one stage of the investigation, the air in the chamber was so depleted of oxygen that when the subjects wanted to smoke, their matches would not light, but they had suffered no discomfort whatever, and were not aware that any change had taken place.

Before leaving entirely the matter of the chemical composition of the air and its relative importance, it is not impossible that in reaching their conclusions, the criteria adopted by these workers were not entirely appropriate nor the measurements sufficiently precise to detect harmful effects that actually did exist. Also, it is well to reflect that such studies as have been made with human subjects have lasted only a few hours at a time. The apparent ability of the human being to withstand other than normal concentrations of atmospheric gases for brief periods, in no way warrants the assumption that prolonged or repeated exposure to abnormal mixtures would turn out to be equally harmless.

This brings us to the second phase of air and its relation to health—a consideration of its physical factors, of temperature, humidity and motion. In these same experiments of Hill's it was found that as the temperature and humidity rose in the chamber, the men became uncomfortable; their pulse rates and body temperatures rose until the condition became almost insupportable. The condition was immediately relieved when the fans were turned on, and became almost as suddenly unbearable when they were turned off again. One of the subjects breathing air from outside the chamber through a tube experienced the same discomfort as his fellows, while Dr. Hill, outside the chamber and breathing the air from within, suffered no discomfort whatever.

These experiments led to the conclusions that have been succinctly summarized by Professor Frederic S. Lee, as follows: "The *ordinary* problems of ventilation are physical and cutaneous rather than chemical and pulmonary."

With these facts apparently established on a scientific basis, the American Society of Heating and Ventilating Engineers in 1922 inaugurated a series of investigations in collaboration with the United States Bureau of Mines and the United States Public Health Service, to determine the comparative effects of various combinations of temperature, humidity and motion of the air on physiological reactions in human subjects. The work is still in progress, but the results of many important phases of the subject have been described in papers by Dr. W. J. McConnell, and Messrs. F. C. Houghten, C. P. Yaglou and others, published in the Annual Transactions of the Society.

In the Society's Research Laboratory at the Pittsburgh Experiment Station of the United States Bureau of Mines, a special room was constructed on the principle of a large refrigerator, so that the effects of outside conditions might be entirely eliminated, and it was equipped with apparatus that would maintain a constant supply of air at any desired temperature from below freezing to above 160° F.; at any desired relative humidity, from practically none to 100%, and at any desired velocity between still air and 700 feet per minute.

Comfort Depends on the Physical Qualities of Air

IN the previous article, it was shown that the physical factors of the atmosphere are *ordinarily* of more importance than any possible variation in its chemical composition. Note the word "ordinarily." There are, in industry, chemical hazards which no adjustment of the physical condition of the atmosphere could compensate, but those are matters out of the ordinary, and outside the scope of this discussion.

It was shown that for the relatively brief duration of the laboratory experiments, discomfort and general dissatisfaction with air conditions vary with the temperature, humidity and motion of the air and not with the slight chemical changes that take place in the air of a room due to the respiration of its occupants. As a general rule, however, it would seem logical that we should breathe only the cleanest air and that which most nearly compares in chemical composition with the uncontaminated air of the open spaces. Otherwise, doubtless, we should have evolved along different lines.

Even before the investigations were commenced at the Pittsburgh Research Laboratory of the American Society of Heating and Ventilating Engineers to determine the exact influence of each of these physical factors, it was recognized that under identical temperatures as registered on a dry bulb thermometer, the air condition felt different at different times. One cause of this was known to be the fluctuation in the amount of water vapor, and this served as the basis for the well-known expression: "It's not the heat; it's the humidity!" It had also been observed that a temperature that seemed perfectly comfortable in still air felt uncomfortably cool when a breeze was blowing, or temperatures that were uncomfortably warm in still air were perfectly agreeable with a breeze.

Not many of us check thermometer readings against our sense of comfort, but should this be done systematically, the results would be found in accordance with these observations. The dry-bulb temperature then is by no means always a completely satisfactory indicator. The relative humidity of the air and its velocity help to determine, with the temperature, whether any air condition is comfortable or not. The matter is still further complicated by the amount of physical work that is being performed, by the quantity and quality of the clothing worn, by acclimatization, and finally—or at least we now think it is final—the temperature of the enclosing wall surfaces.

It should be fairly clear from this that conditioning air for comfort is by no means a simple matter; it is, on the contrary, a highly technical and complicated one. But I am getting ahead of my story!

After a series of preliminary studies to determine the appropriateness of the technique and the suitability of the apparatus and the criteria, Messrs. Houghten, Yaglou and Dr. McConnell made a most elaborate investigation to determine the combinations of temperature, humidity and motion of the air that gave the same sense of comfort to three or four adult male subjects. A view in one of the rooms during these tests is shown in Figure 1.

The tests were made by setting up a clearly defined condition in one of the two test chambers, and varying the temperature, humidity or motion of the air in the other—according to the factor that was the special object of study—until the conditions in the two rooms felt equally comfortable.

Similar tests were made with a large mixed group in still air. Some of the people who participated in this study are shown in Figure 2. The results were tabulated and plotted on a psychrometric chart, as shown in Figure 3. It looks rather complicated, but a little study will show that it is really fairly simple. Across the bottom of the chart on the horizontal scale are ranged the dry bulb[1] temperatures from 30° to 120° F. On the vertical scale are indicated amounts of water vapor per pound of dry air.

The uppermost curve on the chart shows, by reference to the scale at the right, the grains of water vapor in the space occupied by a pound of dry air when the space is saturated at the dry bulb temperatures indicated on the horizontal scale. Strictly speaking, air does not contain water vapor; the two occupy the same space at the same time. For example, at the left hand edge of the chart, we see that at 30° F., at satu-

[1]The dry bulb temperature is the temperature recorded by the ordinary type of thermometer. There are good and bad thermometers, and a bad one is no good. Temperature observations should always be made with care to see that they are free from the influence of factors which would give erroneous results.

ration, there are about 25 grains of water vapor per pound of dry air; at 70°, following the upper curved line of the chart, and referring to the quantities indicated at the left, there are 115 grains—almost five times as much—at saturation. From the other *curved* lines, it is possible to determine the quantity of water vapor for any degree of saturation—relative humidity (1)—and any dry bulb temperature within the limits of the chart.

In addition to the vertical and the curved lines, there are two sets of straight lines that have a common origin with the dry bulb line in the saturation curve — 100% relative humidity. These two sets of lines are the "wet bulb temperature" (2) and (3) the "effective temperature" lines, respectively. While the former is of importance in making determinations of the "relative humidity" and "effective temperatures" from observations with a sling psychrometer, it is the "effective temperature" line in which we are particularly interested.

(1) The relative humidity is the ratio of the actual amount of water vapor in space to the amount it could contain at that temperature.

(2) The wet bulb temperature is the temperature obtained by whirling a thermometer the bulb of which is covered with a wick, moistened in distilled water. The wet bulb depression, the difference between the dry bulb and wet bulb temperatures taken under these conditions is a function of the relative humidity of the atmosphere.

(3) The effective temperature is the temperature of still air at saturation, which gives the same sense of comfort as any other combination of temperature, humidity and air motion.

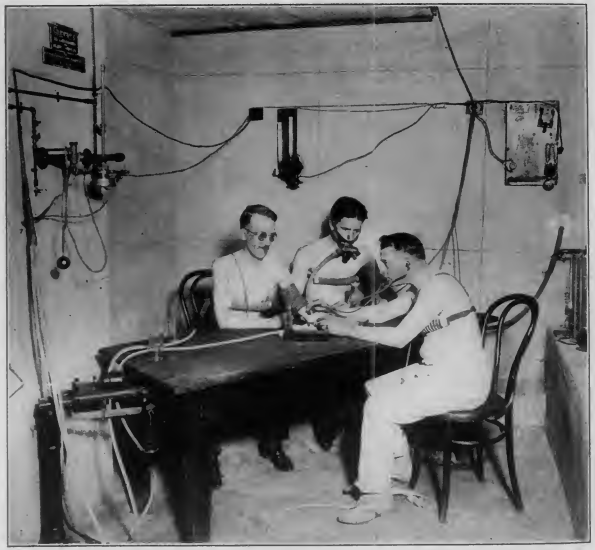

Figure 1—VIEW IN TEST ROOM DURING THE PRELIMINARY STUDIES. PHYSIOLOGICAL REACTIONS WERE RECORDED FOR ALL THE SUBJECTS UNDER THE VARIOUS ATMOSPHERIC CONDITIONS

These workers in the Society's Research Laboratory determined that under the test conditions, any combination of temperature and humidity falling on the same effective temperature line was equally comfortable. Taking the 65° effective temperature line, for example, because it is plainly marked, it will be seen that the following conditions were found to be equally comfortable for persons normally-clothed and slightly-active, in still air.

Table III

COMBINATIONS OF DRY BULB TEMPERATURE AND RELATIVE HUMIDITY CORRESPONDING TO EFFECTIVE TEMPERATURE 65° F.

Dry Bulb Temperature	*Relative Humidity**
65.0	100
65.8	90
66.6	80
67.4	70
68.2	60
69.0	50
69.8	40
70.6	30
71.4	20
72.2	10
73.0	0

*Percent of Saturation.

In other words, the average normally-clothed, slightly-active adult would feel equally comfortable while the dry bulb temperature varied over 8 degrees, provided the air were practically still and appropriate adjustment were made in the relative humidity. This shows clearly that the ordinary thermometer, even if it is accurate, is not a reliable guide to comfort. It shows why a normal person may feel either too hot, too cool, or just right when the thermometer indicates that the air temperature is 68° or 69°. Because relative humidities only rarely go so low as 10% or 15% it suggests that temperatures much above 72°, unless there is a breeze, are generally not desirable, and at the other end of the scale, because humidities are always below saturation, why ordinarily clothed individuals, at rest, will generally find an air temperature of 65° uncomfortably cool.

Of course, it must not be expected that these *average* conditions will be suitable for every individual all the time. Allowance must be made for personal idiosyncrasies, for differences in clothing habits, and for acclimatization. Elderly persons and others whose neuro-vascular systems do not respond normally to temperature changes may constantly require higher temperatures than are comfortable for most of us. The traditional Briton, living in his stone or brick house, heated only by open fireplaces, wears heavy woolens and appears to survive in temperature of 55° to 60° F., at least as well as do the residents of the United States, who doubtless wear less and lighter clothing, but feel that they must have in-

Figure 2—SOME OF THE PERSONS WHO PARTICIPATED IN THE STUDIES OF "EFFECTIVE TEMPERATURE" AND THE "COMFORT ZONE" AT THE RESEARCH LABORATORY OF THE AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS

door temperatures of 68°, 70° or 72° in the winter time.

The fact that we appear to get along and feel comfortable in the summer time at much higher temperatures than we enjoy in the winter is explained by the fact that we slowly become acclimatized—accustomed to higher temperatures. At such times, an air temperature of 68° or 70° which feels all right in the winter time, may cause a distinct shock. On the hottest day in the summer of 1930, I went into one of the movie palaces in New York, as much to get cooled off, as for the show. The temperature in the lobby was 76°, whereas on the street it had been 100° or more. For the first ten or fifteen minutes, I was so cold that I thought I'd be forced to leave, but the longer I remained the more comfortable I became, and I greatly regretted leaving when the program was over.

This is hardly the place for a recital of personal experiences and, as Kipling did in *La Nuit Blanche*, I most emphatically deny that the following observation is based on anything that has actually happened to me. I venture to suggest, however, that family arguments may frequently have their origins in the different reactions to the air conditions in the home, of the lady of the house and her spouse.

Scientists, who are interested in the problem, have counted and weighed the articles of clothing worn by men and women. Their investigations have confirmed opinions based on casual

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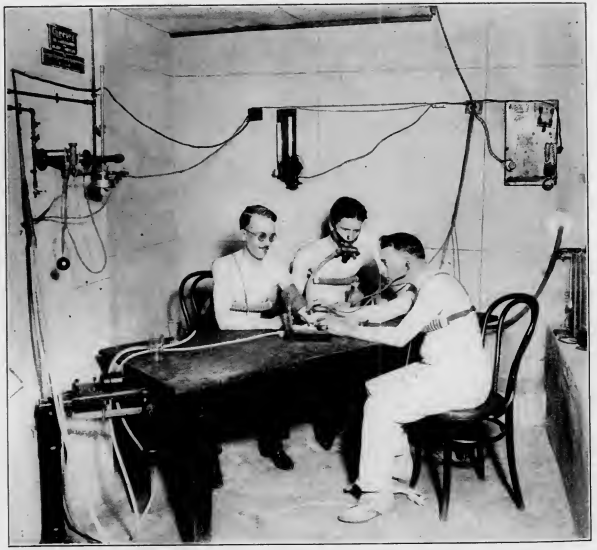

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Scientists, who are interested in the problem, have counted and weighed the articles of clothing worn by men and women. Their investigations have confirmed opinions based on casual

observations to the effect that the clothing of the average adult human female in the United States weighs about one-third of that worn by her husband. Is it any wonder then that a man in the average coat, vest, shirt and undershirt, to name merely those articles above his waist, will be hot and bothered in a temperature perfectly comfortable for his wife, obviously—without going into details—more sensibly clad?

One further bit of scientific evidence may be adduced to explain, if not excuse, the irritability of the male, and for such value as it may have, I pass it along. It has been one of the consistently outstanding by-products of all the studies of the effects of air conditions on man that as the temperature increases, ire likewise rises. Professor Leonard Hill reported that subjects entered the test chamber laughing and chatting, but as the temperature rose they ceased to talk to each other. In the Pittsburgh studies at the Research Laboratory of the American Society of Heating and Ventilating Engineers, even more extreme reactions of this sort were noted by Dr. W. J. McConnell, who not only conducted those studies, but participated in them as well.

Might it not, then, be the part of wisdom to maintain a cool atmosphere in the home and thus avoid the underlying conditions which cause irritability rather than to admonish the tempery male to "keep cool!" in a temperature of 80°?

A further consideration shows why, in the absence of artificial humidification, higher temperatures are usually required for comfort in the winter time than in summer. Starting at the left hand edge of the chart we see that even if we have saturation in the outdoor air at 30 degrees, we have but 25 grains of moisture per pound of air. When this air is heated to 70 degrees, it expands and although saturated at the outdoor temperature, its relative humidity at 70 degrees is but 25 per cent. From the above table it is evident, by interpolation, that a temperature of approximately 71 degrees is necessary to produce the same degree of comfort as

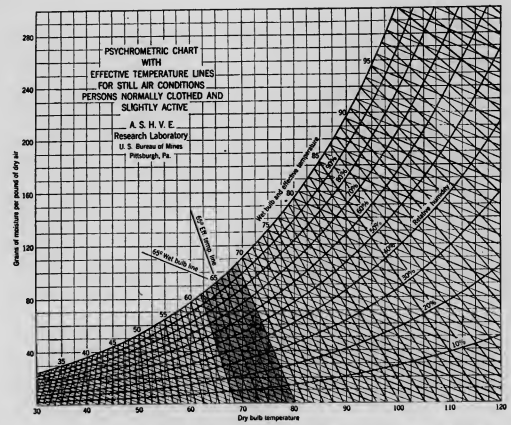

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Figure 3— PSYCHROMETRIC CHART WITH EFFECTIVE TEMPERATURE LINES FOR STILL AIR. SHADED AREA INDICATES THE COMFORT ZONE

would have been enjoyed at 65 degrees if the air were humidified to saturation, or at 69 degrees if the relative humidity were 50 per cent.

Incidentally this condition of 65 degrees "effective temperature" was found to be the most generally comfortable for the hundreds of subjects who were employed in the tests. Other charts present data for various rates of air motion, but the chart shown in Figure 3 is the one most frequently used, because higher air velocities than those on which this chart was based are not ordinarily experienced in homes, schools and offices where comfort is desired.

Summarizing this paper, the dry bulb temperature alone is not a sufficient indicator of comfortable air conditions; the relative humidity and air velocity must also be known in order that the "effective temperature" may be determined. Physiological reactions have been shown to be more closely associated with "effective temperatures" than with either the dry bulb or the wet bulb temperature alone, but that equally comfortable conditions are equally healthful is yet to be determined.

Control of the Physical Factors of the Atmosphere

BEFORE advancing too far with this discussion, we should understand clearly what we mean by health. In the preface to his recent book, *The Diagnosis of Health*, Dr William R. P. Emerson, Professor of Pediatrics, Tufts College Medical School, states that ". . . ideas regarding health remain matters of opinion rather than the results of careful investigation."

In the opening paragraphs on page 3 of the same book, he continues: "The word health is generally accepted to mean a condition of body free from physical disease. By disease is meant any departure from health presenting marked symptoms. Thus we see that health is a relative term."

Health is defined in terms of disease and perhaps we can do no better than to consider the influence of air conditions on the welfare of persons suffering from certain recognized diseases. To this discussion may be added a consideration of the physiological reactions in normal individuals as a result of variations of the physical factors of the atmosphere—the temperature, humidity and motion of the air.

Volumes have been written on these subjects. Bigger and better ones will doubtless follow, but this is not destined to be one of them, and the difficulty lies in trying to tell so much in so little space. However, let it be clearly understood that we are omitting from this further discussion all reference to the chemical composition of the air. It is assumed that everyone knows that the pollution of the atmosphere by smoke, soot and poisonous gases from the chimneys of our industrial plants ought to be stopped.

A Dutch investigator has reported that sufferers from hay-fever and some other forms of protein sensitivity have been able to keep at work regularly during the period of prevalence of the particular pollen or other agency which ordinarily caused distress, by sleeping three or more nights per week in a dust-free atmosphere, of which the temperature, relative humidity and rate of change were mechanically controlled. The relief afforded by untroubled rest and by the soothing effect on the membranes of the respiratory tract by the cool, dust-free air at a favorable relative humidity, so benefited these sufferers that as long as they continued the prescribed course of exposure to cleaned, controlled atmospheres at night, they were free from symptoms even though they continued to conduct their affairs in a normal manner during the daytime.

Although the science of air-conditioning is further advanced in the United States than in any other nation on the face of the globe, and installations of apparatus of American design and manufacture are to be found in the Far East, India, South Africa and South America as well as in all the larger European countries, medical men in the United States appear to have lagged behind their confreres in other countries in taking advantage of the benefits offered by scientifically manufactured atmospheres. This may be due in part at least to the publicity given the faulty conclusions of a group of American investigators, who neglected, in setting up their studies of the effects of different methods of school ventilation on the health of the pupils, on the one hand, to determine either the appropriateness or objectivity of the criterion they used, and on the other to make certain that comparable groups of pupils were exposed to the different conditions under investigation. Their findings *appeared* to

condemn mechanical ventilation, whereas a scientific consideration of the very data they collected and a repetition of the experiments on a larger scale, with carefully balanced groups, showed clearly that there was no valid basis for such a conclusion.

There is, however, a distinct tendency among medical men in the United States today to give more attention to the therapeutic value of mechanically conditioned air. In a recent issue of *Heating, Piping and Air Conditioning* (May, 1930), Dr. Robert F. Morrison presented a paper entitled "Curing Hay Fever with Controlled Weather." Among other things, he says:

> "Hay fever is due, as has been seen, to atmospheric irritants and, as the present methods of treatment are largely preventive it seems logical to conclude that controlled weather affords a reasonable means of treating hay fever. Washed air, in a hospital, would eliminate all dangers from irritants in the nature of dusts, fumes and, to a considerable extent, odors. The temperature would be uniform. Drafts would give place to fixed air motion which, at low speeds, is hardly noticeable. Best of all the temperature, humidity and air motion could be adjusted to give real human comfort as far as atmospheric conditions are concerned. This latter feature would mean much in preventing fevers and in maintaining normal conditions as to the nerves." . . .
>
> "Hay fever, as can be readily seen, often is due to physical conditions similar to those had in various forms of sinus diseases. Many specialists send patients with the latter trouble to high altitudes. At the same time numbers of those with sinus troubles have been greatly benefited by living at the seashore. In both cases the pure air appears to be one of the benefits obtained by the change. At the same time there can be no doubt that the higher humidity of the ocean beach, added to the small amount of salt in the air, has a healing effect that is not obtained in the mountains. From this it appears evident that hay fever, and sinus diseases as well, might be cured by air conditioning at higher humidities where the air is permitted to become the carrier of a predetermined amount of salt or some other healing chemical."

Figure 4—APPARATUS USED TO MEASURE BODY TEMPERATURE OF SUBJECTS IN A TEST TO DETERMINE PHYSIOLOGICAL REACTIONS TO VARIOUS ATMOSPHERIC CONDITIONS

In other places, other medical workers have been considering the use of controlled atmospheres in the treatment of pneumonia, and its effects have been under investigation for some months. Others have been testing the use of air-conditioning in producing fever, where such treatment appears to be indicated. An advanced tuberculosis specialist has been investigating the possibility of equipping an experimental room in his sanatorium. Experiences with hay-fever suggest that tuberculous patients suffering from similar conditions might be relieved and permitted to conserve their energy for their major battle.

But we should not dismiss the subject of hay-fever and similar diseases without telling the story of the gentleman from San Antonio. It so happens that that progressive Texas city has the first completely air-conditioned office building in the world. The gentleman who is the subject of this story had been for years a sufferer from hay-fever. Just as he was beginning to be afflicted in the summer of 1929, he called on one of his clients who had recently taken quarters in this modern building. The relief he enjoyed was so immediate and so complete that he took quarters in the building later. As the summer heat became intense and his business would not permit him to stay in the office as much as necessary during business hours, he installed a cot in the office and spent several nights there each week. For the first time in years, he enjoyed freedom, and it is no wonder that he wrote such a letter of gratitude to the man whose fundamental work formed the basis on which the air-conditioning system had been developed.

It has been said, although I have these reports at second hand, so to speak, that the managers of air-conditioned movie-houses have their troubles in the summer time with hay-fever sufferers who arrive as soon as the doors are opened and after seeing the picture, seek out the best lighted spots, where, with paper or book, they remain until they have to go out for meals, or the theatre closes.

Before concluding this article it might be well to turn our attention again for a moment to the poor normal human. In an earlier article, it was stated that the investigations of the Research Laboratory of the American Society of Heating and Ventilating Engineers had clearly shown that as far as his relation to his atmospheric environment was concerned, man's sense of comfort depended on the combined effect of the temperature, relative humidity and motion of the air and on the temperature of the enclosing surfaces. From the standpoint of comfort, there appears to be no reason why a deficiency in humidity might not be compensated by a slightly higher temperature, or why the unfavorable effects of high temperatures and humidities might not be overcome by a higher rate of air motion.

Although the sense of comfort at any effective temperature is the same regardless of the adjustment of the several factors that go to make that condition, it has very properly been asked, are all the various possible combinations of temperature, humidity and air motion that may comprise any "effective temperature," equally healthful? More specifically, is an "effective temperature," with very low relative humidity as healthful as the same effective temperature created by a slightly higher relative humidity and slightly lower temperature? Some have said that the excessively low relative humidities of the average home in the northern United States in winter, have caused the nasal mucous membranes to dry out, thus providing a portal of entry for organisms causing common colds and other serious diseases. But there is no scientific evidence on which to base such a statement. We know that furniture, books and fabrics deteriorate in dry atmospheres. If there were no means of replenishing the natural supply of moisture, nasal mucous membranes *might* do the same thing. Then if anyone really knew anything about the cause of the common cold, whether it is infectious or not, and, if so, just what the method of infection is, it *might* be possible to find evidence to support this contention. The mere fact that the two phenomena occur in general at the same time by no means establishes a cause-and-effect relationship between the two. Looking at the other side of the picture, we find physicians sending their patients to warm, dry climates for the cure of some respiratory affections. The whole problem needs more study, and the Society of Heating and Ventilating Engineers plans to investigate these matters in the near future.

Figure 5—AUTOMATICALLY RECORDING RATE AND CHARACTER OF A SUBJECT'S PULSE BEAT IN A STUDY OF THE RELATION OF PHYSIOLOGICAL REACTIONS TO VARIOUS ATMOSPHERIC CONDITIONS

Meanwhile, we know that for normal individuals physiological reactions—body temperature and pulse rate—vary with effective temperatures and not directly with the dry bulb temperature alone. Figures 4 and 5 show how these de-

condemn mechanical ventilation, whereas a scientific consideration of the very data they collected and a repetition of the experiments on a larger scale, with carefully balanced groups, showed clearly that there was no valid basis for such a conclusion.

There is, however, a distinct tendency among medical men in the United States today to give more attention to the therapeutic value of mechanically conditioned air. In a recent issue of *Heating, Piping and Air Conditioning* (May, 1930), Dr. Robert F. Morrison presented a paper entitled "Curing Hay Fever with Controlled Weather." Among other things, he says:

> "Hay fever is due, as has been seen, to atmospheric irritants and, as the present methods of treatment are largely preventive it seems logical to conclude that controlled weather affords a reasonable means of treating hay fever. Washed air, in a hospital, would eliminate all dangers from irritants in the nature of dusts, fumes and, to a considerable extent, odors. The temperature would be uniform. Drafts would give place to fixed air motion which, at low speeds, is hardly noticeable. Best of all the temperature, humidity and air motion could be adjusted to give real human comfort as far as atmospheric conditions are concerned. This latter feature would mean much in preventing fevers and in maintaining normal conditions as to the nerves." . . .
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> "Hay fever, as can be readily seen, often is due to physical conditions similar to those had in various forms of sinus diseases. Many specialists send patients with the latter trouble to high altitudes. At the same time numbers of those with sinus troubles have been greatly benefited by living at the seashore. In both cases the pure air appears to be one of the benefits obtained by the change. At the same time there can be no doubt that the higher humidity of the ocean beach, added to the small amount of salt in the air, has a healing effect that is not obtained in the mountains. From this it appears evident that hay fever, and sinus diseases as well, might be cured by air conditioning at higher humidities where the air is permitted to become the carrier of a predetermined amount of salt or some other healing chemical."

Figure 4—APPARATUS USED TO MEASURE BODY TEMPERATURE OF SUBJECTS IN A TEST TO DETERMINE PHYSIOLOGICAL REACTIONS TO VARIOUS ATMOSPHERIC CONDITIONS

In other places, other medical workers have been considering the use of controlled atmospheres in the treatment of pneumonia, and its effects have been under investigation for some months. Others have been testing the use of air-conditioning in producing fever, where such treatment appears to be indicated. An advanced tuberculosis specialist has been investigating the possibility of equipping an experimental room in his sanatorium. Experiences with hay-fever suggest that tuberculous patients suffering from similar conditions might be relieved and permitted to conserve their energy for their major battle.

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terminations were made in the studies at the Society's Research Laboratory. Men stripped to the waist, thus approximating conditions of men engaged in hot industries, sitting at rest, doing no physical work showed increasing body temperatures and increased pulse rate whenever the effective temperature exceeded 85° F. Strangely enough, it appears that the pulse rate is the more sensitive index of reaction to high temperatures. Body temperatures respond more slowly. Had the men been standing or at work, these reactions would without doubt have set in at lower effective temperatures. The same thing would have been true had the subjects been normally clothed.

In the absence of information to the contrary it is fair to assume that the most generally comfortable conditions are the most healthful, and that an effective temperature of 65° F. particularly if it is obtained with a relative humidity of not less than 30% should prove, on this assumption, to be the most healthful condition for average adults in the United States.

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TITLE